Airborne Topographic LiDAR Report

Wisconsin Coastal Management 2015-16 LiDAR Project Report: Manitowoc County

July 9, 2016

Prime contractor: Ayres Associates Inc
Airborne LiDAR Acquisition Completed by Quantum Spatial, Inc.

AYRES ASSOCIATES quantum SPATIAL

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1. Summary / Scope

1.1. Summary

This report contains a summary of the Wisconsin Coastal Counties LiDAR Data Collection for Manitowoc County, issued by Ayres under their Task Order 18 dated September 21, 2015. The task order yielded a project area covering approximately 602 total square miles over Manitowoc County, Wisconsin. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic LiDAR was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
≥ 2 pts / m^2	1,700 m	38°	30%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers approximately 602 square miles and entirely covers Manitowoc County, Wisconsin. LiDAR extents are shown in Figure 1 on the following page. A buffer of 100 meters was created for the area.

1.4. Duration

LiDAR data was acquired from November 2, 2015 to November 10, 2015 in five total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no issues to report with this project.

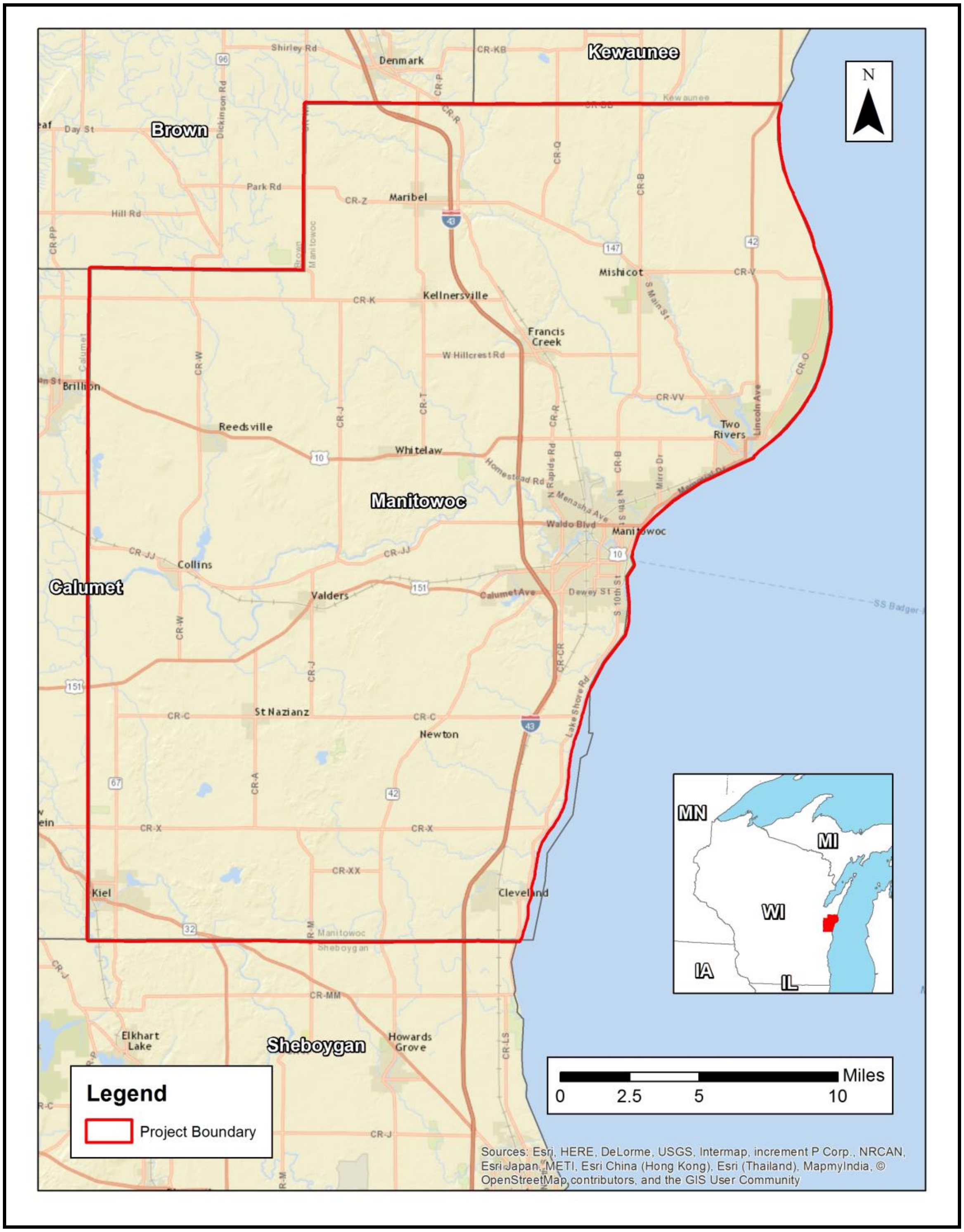
1.6. Deliverables

The following products were produced and delivered for processing:

- Flight plans in digital format
- As-flown flight lines in Esri shapefile format
- Flight logs and notes
- Flight Quality Control Report
- WISCORS and supplemental base station data and OPUS reports
- LiDAR point cloud data, tiled, in LAS 1.4 format
- LiDAR point cloud data, in raw swaths, in LAS 1.4 format
- SBET/ABGPS/IMU materials and documentation
- Trajectories in .TRJ format
- All Flight mission parameters appropriate for inclusion in FGDC/USGS compliant metadata

All geospatial deliverables were produced in NAD83 (2011) WISCRS Manitowoc County, US survey feet; NAVD88 (Geoid 12A), US survey feet. All tiled deliverables have a tile size of 4,500 feet x 4,500 feet.

Figure 1. Project Boundary



2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity.

Detailed project flight planning calculations were performed for the project using Optech MissionNAV planning software. The entire target area was comprised of 57 planned flight lines measuring approximately 2,157.80 total flight line kilometers (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized an Optech Orion H300 LiDAR sensor (Figure 3), serial numbers 324 and 329 during the project. These systems are capable of collecting data at a maximum frequency of 300 kHz, which affords elevation data collection of up to 300,000 points per second. These systems utilize a Multi-Pulse in the Air option (MPIA). These sensors are also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. The intensity of the first four returns is also captured during aerial acquisition.

A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specifications in Table 2.

Figure 2. Planned Flight Lines

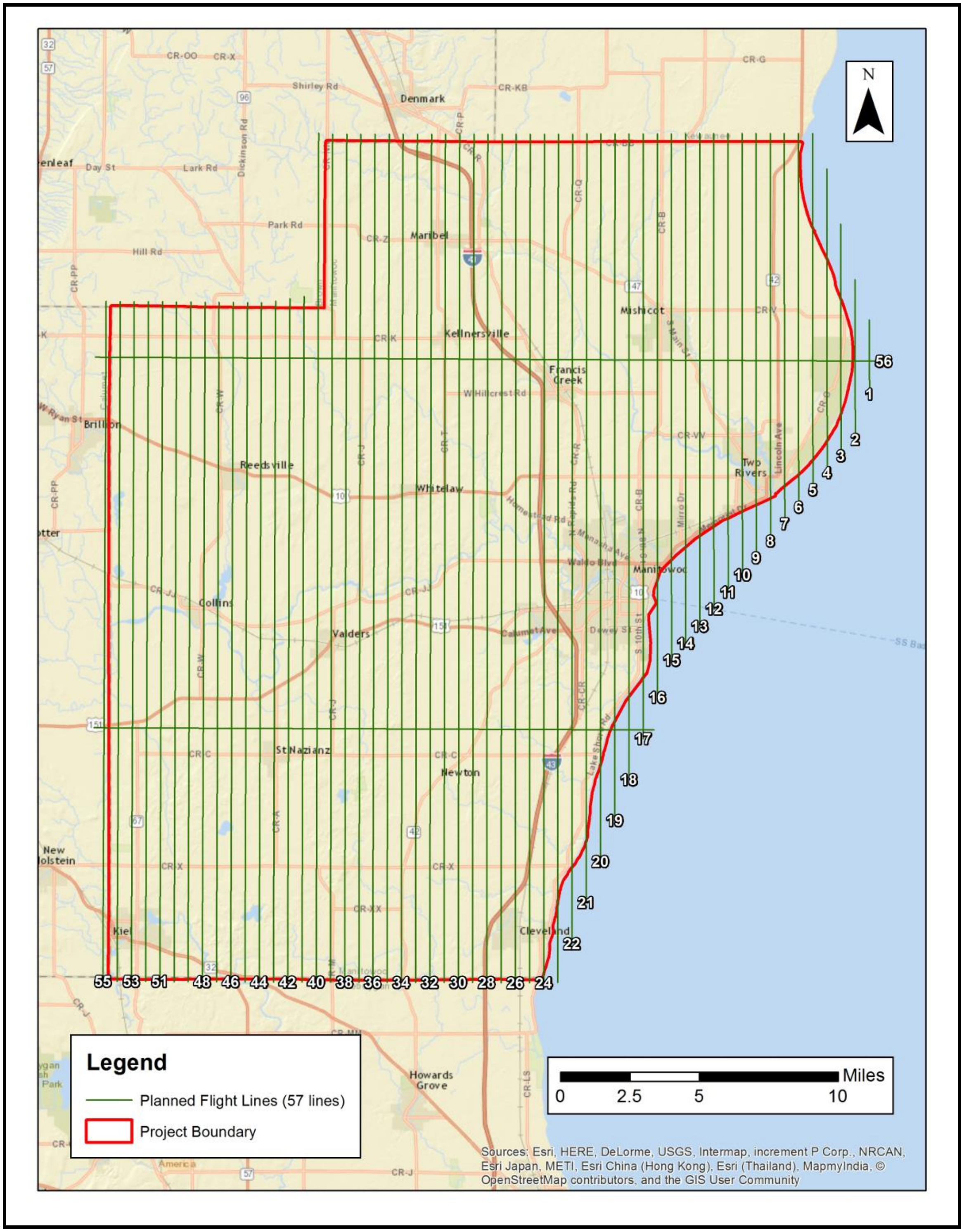


Table 2. LiDAR System Specifications

Terrain and Aircraft Scanner	Flying Height	1,700 m
	Recommended Ground Speed	140 kts
Scanner	Field of View	38°
	Scan Rate Setting Used	52 Hz
Laser	Laser Pulse Rate Used	225 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width	1,170.71 m
Point Spacing and Density	Average Point Density	2.19 pts / m^2

Figure 3. Optech Orion H300 LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of the following customized aircraft:

- Piper Navajo (twin-piston), Tail Number N73TM
- Partenavia P68-C (multi-piston), Tail Number N300LF.

These aircraft provided an ideal, stable aerial base for LiDAR and orthoimagery acquisition. These aerial platforms have relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Optech LiDAR system. Some of Quantum Spatial's operating aircraft can be seen in Figure 4 below.

Figure 4. Some of Quantum Spatial's Planes

2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 3). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 5. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 3. Base Station Locations

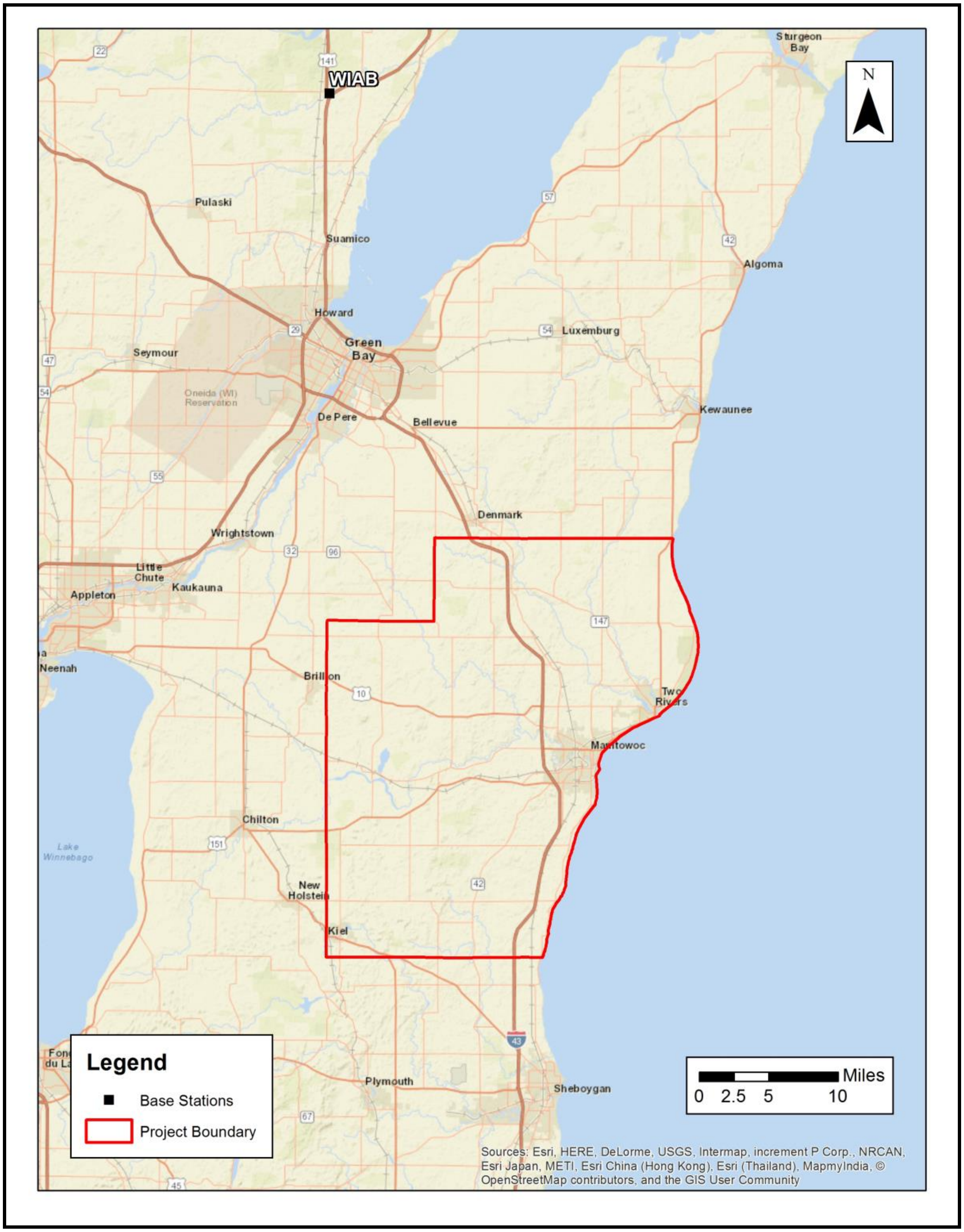
Base Station	Latitude	Longitude	Ellipsoid Height (m)
WIAB	44° 47' 27.29874"	88° 2' 42.18794"	167.06

2.5. Time Period

Project specific flights were conducted over three days. Five sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- Nov 2, 2015-B (N300LF, SN329)
- Nov 9, 2015-A (N73TM, SN324)
- Nov 9, 2015-B (N73TM, SN324)
- Nov 10, 2015-A (N73TM, SN324)
- Nov 10, 2015-B (N73TM, SN324)

Figure 5. Base Station Locations



3. Processing Summary

3.1. Flight Logs

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. LiDAR Processing

Applanix + POSPac Mobile Mapping Suite software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. POSPac combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Applanix POSPac processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant graphs produced in the POSPac processing environment for each sortie during the project mobilization are available in Appendix A.

The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into TerraScan and a manual calibration is performed to assess the system offsets for pitch, roll, heading and scale. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above-ground features are removed from the data set. Point clouds were created using the Optech DashMap Post Processor software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

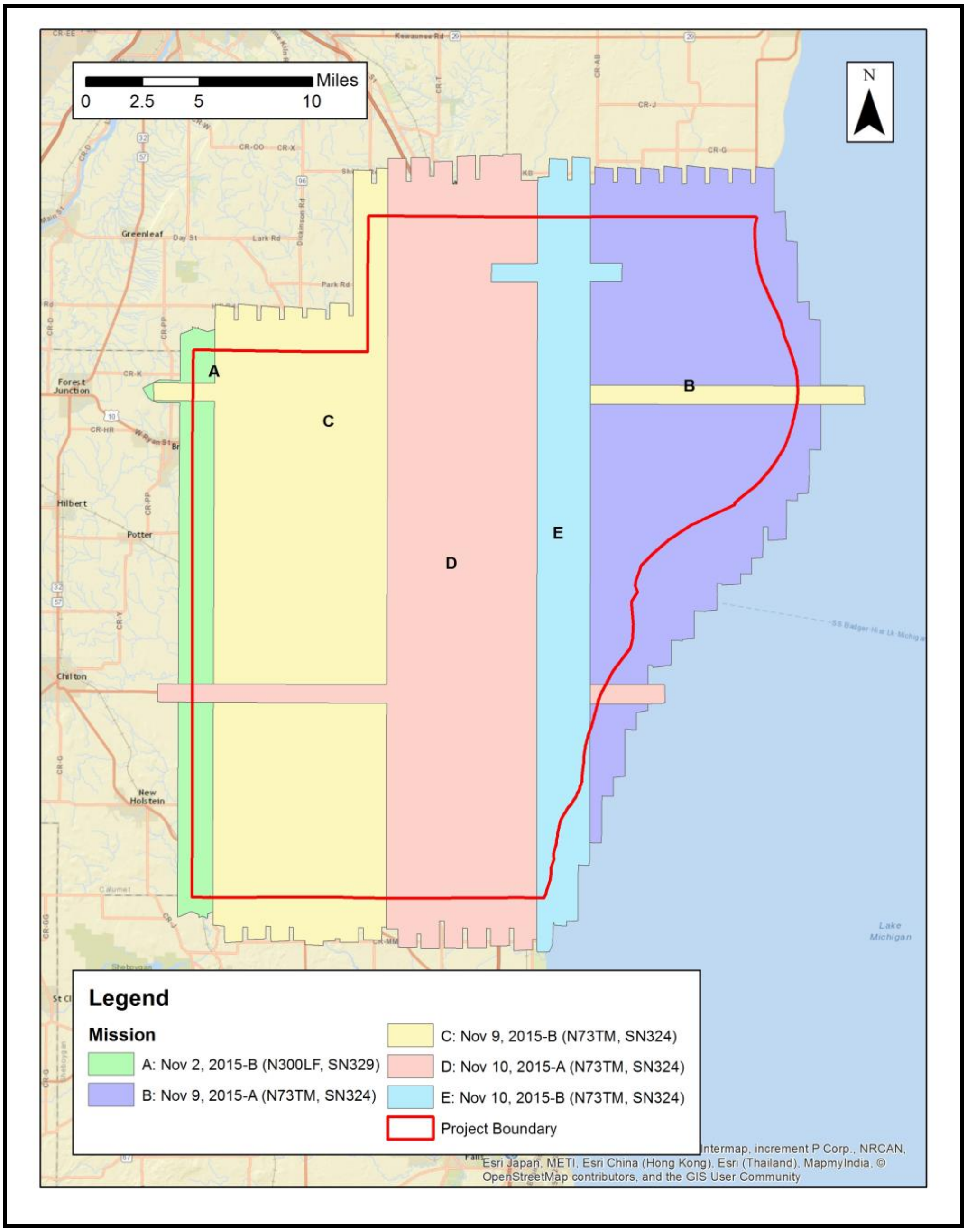
All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the dataset. GeoCue was used to create the deliverable industry-standard LAS files for the All Point Cloud Data.

4. Processing Summary

4.1. Flight Logs

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 6.

Figure 6. Flight Line Swath LAS File Coverage



5. Ground Control Point Collection

5.1. Point Collection

Quantum Spatial utilized 15 ground control (calibration) points as an independent test of the accuracy of this project. In this document, horizontal coordinates for ground control points are reported in NAD83 (2011) WISCRS Manitowoc County, US survey feet; NAVD88 (Geoid 12A), US survey feet.

5.2. Calibration Point Testing

TerraScan was used to perform a quality assurance check for each of the LiDAR bare earth calibration points. Note that these results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface. See Figure 7 and Table 4.

Figure 7. Calibration Control Point Locations

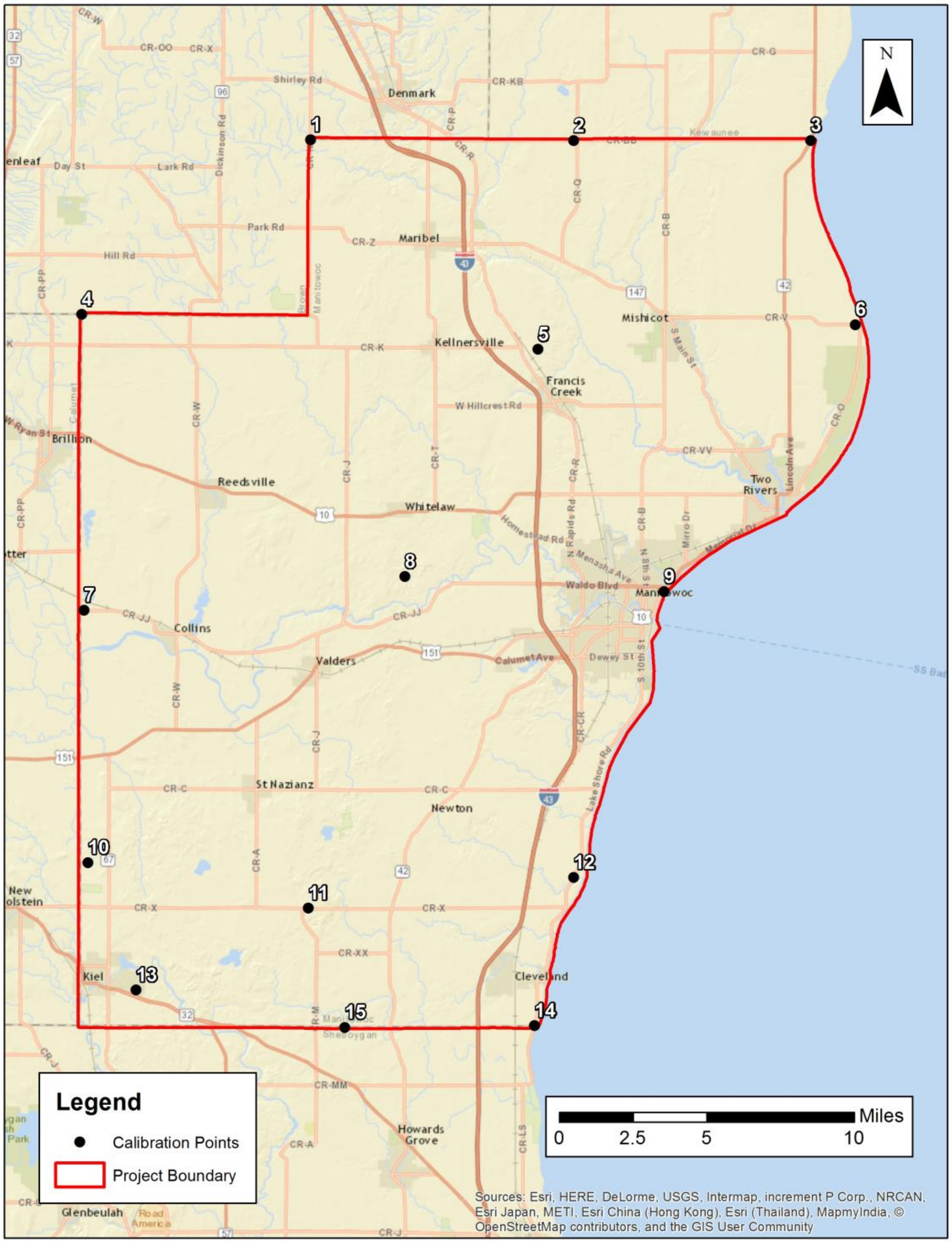


Table 4 Originally Planned LiDAR Specifications

Number	Easting	Northing	Known Z	Laser Z	Dz
1	173650.030	386810.730	856.980	857.470	+0.490
11	173251.580	249247.110	910.410	910.700	+0.290
14	213733.490	228199.670	638.630	638.820	+0.190
10	133830.900	257417.350	884.790	884.890	+0.100
6	271157.950	353729.500	595.460	595.520	+0.060
4	132698.890	355565.210	890.980	891.030	+0.050
5	214388.730	349325.550	744.650	744.670	+0.020
8	190557.000	308629.440	793.960	793.920	-0.040
12	220712.110	254725.940	600.400	600.330	-0.070
15	179762.730	227904.680	803.020	802.950	-0.070
7	133076.510	302598.680	832.880	832.770	-0.110
2	220725.570	386676.370	736.390	736.250	-0.140
9	236894.310	305907.500	596.180	596.040	-0.140
13	142404.360	234600.190	895.540	895.400	-0.140
3	263181.300	386710.930	622.420	622.240	-0.180

Average Dz	+0.021 ft
Minimum Dz	-0.180 ft
Maximum Dz	+0.049 ft
Root Mean Square	0.181 ft
Standard Deviation	0.186 ft